

Geoff Shester
796 Escondido Rd. #15L
Stanford, CA 94305
gshester@stanford.edu

Dr. James Balsiger
Alaska Regional Administrator
National Marine Fisheries Service
P.O. Box 21668
Juneau, AK 99802-1668

Submitted via email to: ak.efheis.comments@noaa.gov on April 14, 2004

RE: Review of Literature Not Used in Alaska Region EFH DEIS

Dear Dr. Balsiger,

In addition to the comments I have sent via mail, I would like to submit the attached literature review summary as comments on the Alaska Region EFH DEIS. This literature review summary contains 193 references that NMFS were not included in the Alaska Region Essential Fish Habitat Draft Environmental Impact Statement and 3 additional studies with key results that were not incorporated in the EFH DEIS. These omissions represent a substantial body of the best available science that was not considered or incorporated into the analysis, methodologies, or conclusions of the EFH DEIS. This body of literature contains results that are contrary to several major assertions and conclusions made in the EFH DEIS.

Of particular note is that many scientific studies have found that bottom trawling reduces the quality and/or quantity of structural habitat on the seafloor and are not considered in the EFH DEIS. A large number of these studies were included in a NOAA Technical Memorandum bibliography (Dieter et al. 2003). This document stated on page 1 of its Introduction that "Ultimately, this literature should aid the NMFS and the eight regional fishery management councils in assessing effects of fishing on EFH." Page 1 also states that "The bibliography is worldwide in scope since the principles of gear disturbance are globally significant." Therefore it is clear that the results of the studies included in the NOAA bibliography are relevant to the effects of fishing analysis conducted by NMFS in the EFH DEIS. The NOAA bibliography was not referenced in the EFH DEIS, though it contains 700 citations on the impacts of bottom fishing gear on fish habitat, most of which were omitted from the EFH DEIS.

Thank you for considering the additional sources of scientific information I have included.

Sincerely,

Geoff Shester
Ph.D. Student, Interdisciplinary Program in Environment and Resources
Stanford University

Attachment: "Lit. Review Summary of References Not Used in Alaska Region EFH DEIS"

Literature Review Summary of References Not Used in Alaska Region EFH DEIS

By Geoff Shester

Interdisciplinary Program in Environment and Resources, Stanford University

Impacts of bottom trawling on biogenic, structurally complex seafloor habitat

1. Heifetz et al. (2003) documented 50% damage to sponges in Eastern GOA one year after a trawl, discussed vulnerability, low recovery rates, and ecological importance of sea whips, and described newly discovered coral habitats in the Aleutian Islands, including damage due to bottom fishing gear.
2. The NMFS Alaska Fisheries Science Center website (NMFS 2004) shows a “spawning male and female Atka mackerel” in deep sea coral habitat in Seguam Pass. This is not considered in the EFH DEIS in any section pertaining to Atka mackerel. The videos shows rockfish, sculpin, halibut, northern rockfish, Pacific Ocean perch associated with corals and sponges. Clip 9 shows heavily trawled coral habitat containing “broken-up coral debris in this area -- heavily damaged”. (http://www.afsc.noaa.gov/race/media/videos/vids_habitat.htm)
3. Armstrong et al. (1993) found that the impacts of red king crab bycatch are obscured by the effects of trawling on juvenile crab habitat and that an emergency closure in 1987 in the E. Bering Sea did not protect important hatching and breeding grounds and juvenile habitat.
4. Ardizzone and Pelusi (1983) and Ardizzone et al. (2000) found bottom trawling to reduce the quality and quantity of *Posidonia oceanica* beds, a biogenic habitat in the Mediterranean Sea.
5. Hall-Spencer and Moore (2000) found a 70% reduction in maerl thalli habitats, which have important ecological functions, with no recovery after four years.
6. Kaiser et al. (1996) conducted a multivariate analysis showing that both beam trawling and dredging reduce the abundance of most epifaunal species in the Irish Sea.
7. Kaiser et al. (2000a) found that chronic fishing has caused a shift from communities dominated by relatively sessile, emergent, high biomass species to communities dominated by infaunal, smaller-bodied fauna. Removal of emergent fauna has thus degraded the topographic complexity of seabed habitats in areas of high fishing effort. The authors note that communities within these areas currently may be in an alternative stable state.
8. Ault et al. (1997) found conspicuous long-term damage to sponges and soft corals after one pass of a trawl and that the sponge *Ircina felix* and corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to breakage or dislodgement by trawling.
9. Collie et al. (1996), Collie et al. (1997), and Collie et al. (2000) found conspicuously and significantly reduced abundance of colonial epifaunal species that provide complex habitat for shrimp, polychaetes, brittle stars, and small fish at sites disturbed by bottom fishing in Georges Bank, and found that many species whose abundances were reduced were also prey for commercial fish.
10. DeAlteris et al. (2000) discuss physical impacts and biological alterations in community structure caused by trawling in New England and recommended closure areas to reduce the impact of mobile fishing gear on habitat and biodiversity.
11. Fossa et al. (2002) developed an estimate of 30-50% of the deep sea coral *Lophelia* reefs in Norway have been damaged by bottom trawling and that fishermen claim that catches are significantly lowered in areas where the reefs are damaged.
12. Kaiser et al. (2000b) found significantly higher biomass and emergent epifauna that increased habitat complexity in areas closed to trawling.

13. Koslow et al. (2001) sampled the benthic fauna of Tasmanian seamounts finding high abundance and diversity of hard and soft corals, hydroids, sponges, ophiuroids, and sea stars, a large fraction of which were new to science. This study also found that heavy trawling has completely removed the reef aggregations and that benthic biomass was 106% greater and species richness was 46% greater on unfished seamounts than fished seamounts.
14. Magorrian (1995) found otter trawling to remove emergent epifauna and reduce the structural complexity of mussel beds in Strangford Lough, and recommended marine reserves as a management tool.
15. McAllister and Spiller (1994) found that trawling and dredging have major impacts on marine habitats by removing protruding invertebrate animal life including sea anemones, sponges, sea squirts, crinoids and many others which provide shelter and food sources for juvenile fish and shellfish. Specific trawling effects in the study included shearing off higher hummocks, filling in low spots, changing the configuration of the bottom, removing areas more exposed to or protected from the current, exposing shellfish, worms and other sediment dwelling species to predation, and stirring up clouds of mud and other sediment that plug gills and similar structures of filter feeders. The authors recommend closures, control areas, and conversions to less damaging gear types.
16. Norse and Watling (1999) found that trawling damages refuges from predation and feeding places for demersal fish, which are correlated with species diversity and post settlement survivorship of some commercial species.
17. Pitcher et al. (2000) found removal rates of most seabed fauna to be 5-20% per trawl based on a five-year study in the Australia's Great Barrier Reef. They also developed a model for fishing impacts to the total populations of seabed fauna incorporating historic fishing effort data, aggregation of trawl effort within each block, and a dynamic model of recovery rates for different habitat features. Total annual removal of benthic fauna ranged from very low to over 80% in areas of highest intensity. They found that highly vulnerable populations may be depleted by about 55% overall and there will be a substantial alteration in most trawled grids with a shift to less vulnerable species. The final report of this study (Poiner et al. 1998) including Before-After, Control Impact studies of trawl impacts were also omitted from the EFH DEIS.
18. Pitcher et al. (1999) contains information on trawl impacts to sponges and other epifauna that was not considered in the EFH DEIS.
19. Reed (2002) in a study of deep water *Oculina* reefs along eastern Florida, noted extensive areas of *Oculina* rubble in part as the result of bottom fishing and major declines in commercial fish populations in the reefs from 1970-1990. Coral growth rates averaged 16.1 mm/yr.
20. Rumohr et al. (1994) found reductions in abundance of epifauna and absence of inner structures (feeding burrows, living chambers, tubes) in areas impacted by trawling in the German Bight.
21. Van Santbrink and Bergman (1994) documented 70% mortality to anthozoans after two passes of a beam trawl in the southern North Sea.
22. Bavestrello et al. (1997) found fishing damage to gorgonian corals in the Ligurian Sea, found slow recolonization and recovery rates for these corals, and recommended special protection for these corals as a Natural Marine Park.

23. Roberts & Hirshfield (2004) provide a comprehensive review of worldwide evidence for trawling impacts to deep sea corals and known fishery associations with these habitat features.
24. Conway et al. (2003) studied the environmental conditions where sponge reefs are found and discovered that like deep-sea coral reefs, many of the hexactinosean sponge reefs in British Columbia have been damaged or destroyed by the groundfish trawl fishery.
25. Grehan et al. (2003) found evidence that deep sea corals are being destroyed by trawling, as evidenced by trawl scars, flattened coral rubble, barren sediment, and lost trawl gear. The authors state that this provides irrefutable proof of a serious threat to the marine ecosystem caused by fishing that warrants immediate emergency measures to protect the remaining corals.
26. Hall-Spencer et al. (2002) document widespread trawling damage to cold-water coral reefs at 840-1300 m depth along the West Ireland continental shelf break and at 200 m off West Norway. The trawled coral matrix was at least 4550 years old. The authors discuss the need for urgent conservation measures to protect these corals.
27. Morgan and Chuenpagdee (2003) interviewed a group of experts on fishing gears and determined that bottom trawling had the highest impact score for biological and physical habitat features compared to other gears such as bottom longlines, pots, and traps.
28. Lundalv and Jonsson (2003) found about 50% of investigated coral sites in the Kosterfjord area to be destroyed by recent fishing activities, while the remaining areas exhibit major signs of trawl damage.
29. Mortensen et al. (2003) found signs of fishing impact such as broken live corals, tilted corals, and scattered skeletons. Broken or tilted corals were observed along 29% of the transects. A total of 4 % of the coral colonies observed were impacted. The authors observed that *Paragorgia* seemed more susceptible to breakage from fishing impacts than *Primnoa* due to its larger size and less flexible skeleton.
30. Stone and Malecha (2003) state that "gardens of corals, sponges, and other sessile invertebrates" were similar in structural complexity to tropical coral reefs with which they shared several important characteristics including complex vertical relief and high taxonomic diversity. The authors note the particular sensitivity of these habitats to disturbance and observed anthropogenic disturbance to corals.
31. Wheeler et al. (2003) Found broken coral rubble and dead coral in areas of higher trawl intensity, whereas untrawled areas had a much higher abundance of undisturbed upright coral colonies. The authors state that even small coral thickets provide "cover" for fish and that destructive removal of this cover may have major implications for local fish stocks and coral associated biodiversity. The authors recommend using the precautionary principle by implementing fisheries technical measures to prevent further damage to coral until more is known about the relationship between fish and corals.

Impacts of trawling on spawning

1. Morgan et al. (1997) found persistent, large-scale disturbance in the structure of a spawning aggregation of cod attributable to one pass of a bottom trawl.
2. Bailey et al. (2003) identified specific locations of spawning habitat of Alaska plaice (*Pleuronectes quadrituberculatus*) in Shelikof Strait and stated that the population in the Gulf of Alaska is limited by recruitment to suitable bottom nursery habitat. The study identifies

locations of high egg, juvenile, and adult density and states that availability of specific infaunal prey types is a specific habitat requirement.

3. Morgan et al. (1999) found adverse effects of trawling on spawning and reproductive success of Atlantic cod due to increased stress.
4. Reed et al. (2003) found that Oculina reefs (deep sea corals off Florida) that were "teeming with fish" in the 1970s have subsequently been destroyed fishing activities with concomitant losses in commercial fish species. Grouper spawning aggregations that were once regularly observed are now absent in the damaged areas.

Impacts of trawling on infauna

1. Boyd and Rees (2000) found significant reductions in numbers of species, biomass, species richness and diversity of benthic infauna in dredged areas relative to undredged areas in the English Channel.
2. Arntz et al. (1994) found that delicate, sensitive species were less abundant in repeatedly trawled areas than in areas protected from trawling in the German Bight of the North Sea.
3. Demestre (2000) confirmed the results of previous studies that increases in scavenger abundance after trawling last no more than several days, indicating that additional food resources made available by trawling are rapidly consumed.
4. Hall-Spencer et al. (1999) found that trawling reduced the abundance of slow-moving or sessile benthic species *Pecten*, *Holothuria*, and *Atrina*.
5. Kaiser and Spencer (1996) conducted an analysis of the effects of trawling on benthic infauna, showing differences between fished and unfished sites were largely due to the removal of less common species and found major decreases in benthic infauna after trawling in areas with stable sediments.
6. Kenny et al. (1996) found a long-term reduction in benthic species biomass after experimental dredging.
7. Morton (1996) found long-term declines in infaunal communities of molluscs and gastropods as the result of trawling and dredging in the southern waters of Hong Kong.
8. Rumohr and Kujawski (2000) found long-term reductions in the frequency of occurrence of bivalve species as the result of trawling impacts in the southern North Sea.
9. Cryer et al. (2002) provide empirical evidence of the large-scale effects of trawling on a deep-water soft-sediment system by demonstrating substantive decreases in the diversity of large benthic invertebrates associated with a continental slope (a depth of 200–600-m) scampi (*Metanephrops challengerii*) fishery. This result emphasizes that the impacts on seafloor communities that have been more readily documented in shallower water are also occurring in deeper water.
10. Snelgrove et al. (1997) found that benthic organisms contribute to regulation of carbon, nitrogen, and sulfur cycling, water column processes, pollutant distribution and fate, secondary production, and transport, and stability of sediments.

Impacts of dredging on benthic habitat

1. Aschan (1991) showed no recovery of several major infaunal species two years after scallop dredging.
2. Bradshaw et al. (2002) found reductions in sessile, fragile taxa as a result of dredging in the Irish Sea.

3. Cranfield (1999) found that dredging in Foveaux Strait, New Zealand reduced patch reefs of bryozoa, ascidians, sponges, and polychaetes that previously had higher fishing success before dredging.
4. Hill et al. (1999) found reductions in fragile benthic species in the Irish Sea as a result of 40 years of dredging.
5. Lindeman and Snyder (1999) studied dredging impacts in hardbottom habitat where 80% of the individuals were early life stage fish and over 20 species were associated with hardbottom structure. One year after dredging, burial of approximately five ha of hardbottom habitat at one site lowered the numbers of individuals and species by over 30x and 10x, respectively. The authors found that many of these species were not adapted for high mobility in response to habitat burial and that effects are amplified by dredging prior to and during periods of peak larval recruitment.
6. Piersma (2001) found long-term changes to several bivalve species as a result of impacts to sediment characteristics caused by bottom dredging in the Wadden Sea.
7. Poiner and Kennedy (1984) found significant decreases in total abundance, species richness and Shannon diversity in dredged areas relative to undredged areas in Queensland, Australia.
8. Quigley and Hall (1999) found that dredging impacted the dredged sites and areas 500 m away and found no significant signs of recovery.
9. Rothschild et al. (1994) found that mechanical destruction of habitat caused by fishing was an important factor in the decline of oysters in Chesapeake Bay.
10. Thrush et al. (1995) found significant alterations in benthic community structure immediately and 3 months after scallop dredging.
11. Veale et al. (2000) found that total abundance, biomass and production, and the production of most of the major individual taxa investigated decrease significantly with increasing dredging effort in the North Irish Sea. The authors found a linear decrease in diversity with increasing fishing disturbance due to selective removal of sensitive species and habitat homogenization.

General effects of bottom disturbance

1. Dayton et al. (1995) asserted that habitat disturbance by fishing is the dominant anthropogenic effect on the marine environment.
2. Dayton (1998) discusses the irreversible "cascading ecological changes" that can occur as the result of bottom fishing, suggesting that the burden of proof be reversed.
3. Fogarty and Murawski (1998) suggest that physical damage to habitat exacerbates the cumulative effects of fisheries exploitation and environmental conditions leading to fisheries depletion.
4. Phillipart (1998) concluded that bottom fisheries have had a considerable impact on several demersal fish species and benthic invertebrates in the North Sea.
5. Reise and Schubert (1987) found significant declines in several epibenthic species of the 1920s as a result of dredging and trawling on the benthic fauna.
6. Relini et al. (2000) found that the spread of new species as a result of bottom trawling and trammel nets resulted in declines in valuable fish and fishermen's income in the Ligurian Sea.
7. Riesen and Reise (1982) found that long-term changes in benthic structure of the Wadden Sea cannot be solely from natural processes, but also from human disturbance, particularly bottom trawling.

8. Sainsbury et al. (1993) found that the composition of the multispecies fish community on the northwest shelf of Australia is habitat dependent and the historical changes in animal composition are partly a result of long-term habitat disturbance due to demersal trawling gear.
9. Thrush et al. (2001) results suggest removal of habitat structure in relatively low-structure soft-sediment systems will significantly decrease their biodiversity, and consequently that of the wider marine ecosystem.
10. Rose et al. (2000) addresses the components of various demersal fishing gears that have the greatest impact on benthic habitat, discusses under what conditions the gear components effects are most pronounced.

Benefits of trawl closures on stock biomass and habitat

1. Pipitone et al. (2000) found an 8-fold increase in total biomass following four years of a trawl closure and significant increases for 10 of 11 target species. This contradicts the conclusions reached in the EFH DEIS that closures will not affect stock size of target species.
2. Vassilopoulou and Papaconstantinou (2000) documented higher total biomass and larger specimens of target species in untrawled areas relative to trawled areas. This contradicts the EFH DEIS assertion that trawl closures will not affect the stock size of target species.
3. Murawski et al. (2000) found significant reductions in fishing mortality and major increases in biomass of several commercial species as the result of large area closures in Georges Bank. The study notes the importance of closures to enhance larval production, protect nursery areas, and spawning concentrations.
4. Lipcius et al. (2003) found that an expanded marine protected area and corridor placed in spawning habitat effectively protected blue crab stocks in Chesapeake Bay.
5. White et al. (2000) showed that the costs of a marine reserve for tropical coral protection were greatly outweighed by the benefits from higher catches.
6. White et al. (2000) showed that the costs of a marine reserve for tropical coral protection were greatly outweighed by the benefits from higher catches.
7. Rodwell et al. (2003) developed a model whose results indicate that habitat protection in reserves can underpin fish productivity and, depending on its effects on fish movements, augment catches. The authors state that "Marine reserves increase total fish biomass directly by providing refuge from exploitation and indirectly by improving fish habitat in the reserve", contradicting assertions in the EFH DEIS that increased closures will not increase stock biomass. This type of model could and should be used to evaluate the effects of management measures.
8. Soh et al. (2001) used GIS analysis and found that marine reserves can greatly protect shortraker and rougheye rockfish populations from habitat impacts, discards, and serial overfishing of substocks without reducing catch levels.
9. Conover et al. (2000) discusses the potential benefits of marine reserves including protecting critical habitats that have been depleted, conserving marine biodiversity, and enhancing the harvest of stocks outside the reserve.
10. Rudd et al. (2003) states that "Fully accounting for the value of ecological services flowing from marine reserves requires consideration of increased size and abundance of focal species within reserve boundaries, emigration of target species from reserves to adjacent fishing grounds, changes in ecological resilience, and behavioural responses of fishers to spatially

explicit closures.” The EFH EIS should analyze and present these benefits in its analysis of measures to mitigate the adverse effects of fishing on EFH.

11. Note that several studies found reductions in commercial fish populations as a result of habitat damage caused by trawling and/or increased catches in coral and sponge habitats (i.e. Reed 2002; Rellini et al. 2000; Rothchild 1994; Sainsbury et al. 1993; Thrush and Dayton 2002; Vassilopoulou and Papaconstantinou 2000; Husebo et al. 2002; Bradstock & Gordon 1983)
12. Christiansen and Lutter (2003) cited an ICES statement that “the only proven method of preventing damage to deep-water biogenic reefs from fishing activities is through spatial closures to towed gear that potentially impact the bottom”.

Biodiversity of deep-sea coral habitats

1. The biodiversity of deep sea sponge habitats is underestimated in the EFH DEIS. Beaulieu (2001) observed 139 taxa associated with deep sea sponge communities in the northeast Pacific.
2. Henry (2001) found thirteen hydroid species collected from only four coral specimens, suggesting that northern corals support highly diverse epifaunal communities.
3. Sanchez and Cairns (2004) identified a new genus of gorgonian coral, *Alaskagorgia aleutiana*, from recent research dives in the central Aleutian Islands. The authors state that most of the species in this the Alaskan octocoral assemblage remain unidentified and/or undescribed.
4. Edinger and Risk (2000) presented a valuation strategy for tropical corals by coral type, incorporating differences in fish productivity and biodiversity of different coral types. The EFH EIS should present all that is known on taxa associated with deep sea corals, sponges, and other biogenic habitats in Alaska.
5. Tilman et al. (1994) developed a model showing that the more fragmented a habitat already is, the greater is the number of biological extinctions caused by added destruction. Because such extinctions occur generations after fragmentation, they represent a debt-a future ecological cost of current habitat destruction. This is particularly relevant to the sections of Chapter 4 that comment on the impacts of each alternative on biodiversity.
6. Buhl-Mortensen & Mortensen (2003) found the species richness of the deep-sea gorgonian coral fauna (*Paragorgia arborea* had 60 associated species and *Primnoa resedaeformis* had 45) in Atlantic Canada to be higher than what has been observed for tropical gorgonians. These included shrimp, copepods, and redfish hiding and resting on and among colonies of both coral species.
7. DeVogelaere et al. (2003) found 24 coral taxa on Davidson Seamount off California and described numerous species associations, particularly that *Paragorgia sp.* were found in areas with highest species diversity.
8. Reyes et al. (2003) found over 100 species of associated fish and invertebrates with deep sea corals at each of three sites sampled in the Caribbean.

Other omissions/contradictions to statements in EFH DEIS

1. Roberts et al. (2000) found evidence for trawling for over 10 years at depths of more than 1000 m on the Atlantic continental slope of north-west Scotland. This contradicts the assertion in the EFH DEIS that depths greater than 1000 m are unfishable.
2. Carr and Milliken (1998) presented several gear modifications to trawl gear for minimizing

fishing impacts to EFH that were not considered.

3. Bizarro (2002) developed maps of coral, sponge and anemone distribution in commercial fishing grounds of SE Alaska specifically for use in the EFH and HAPC processes. The study determined species associations with these habitat features. The results improve the distributions of these habitat types described in the EFH DEIS and suggest additional areas that may warrant protection.
4. The EFH EIS should include seminal works defining and describing adaptive management such as Holling (1978) and Walters (1986). This literature would affect the formulation and analysis of Alternative 5B.

Coral and sponge distribution

1. NOAA's Office of Protected Resources commissioned Marine Conservation Biology Institute (Etnoyer and Morgan 2003) to gather records of deep-sea coral distribution for species exhibiting complex branching morphology and sufficient size to provide substrate or refuge to associated species. A total of 2661 data points were gathered. This does not include fisheries observer data. They found the highest density of data points along the Aleutian Islands chain in Alaska and recommended that these rich coral regions be protected from the impact of bottom trawling.
2. Gass and Willison (2003) used groundfish trawl surveys, fisheries observer data, and historical and current local ecological knowledge of fishermen to develop a map of deep sea coral distribution off Nova Scotia and Newfoundland. It is unclear why this approach was not taken in the EFH DEIS and that the EFH Committee was not utilized for this purpose.
3. Leverette and Metaxas (2003) developed a technique to develop habitat suitability model for deep sea corals that can be used with limited data on coral distribution.
4. Morgan et al. (2003) conducted analysis of coral distributions in the northeast Pacific Ocean and identified areas that are vulnerable to bottom trawling and lightly fished. The authors caution that management aimed at seafloor protection should not inadvertently shift fishing effort to more sensitive seafloor areas such as cold-water coral aggregations.

Evidence for habitat-fishery linkages: Alaska species

1. Stone (preliminary data, 2004) found an 87% rate of association between adult Alaskan FMP species and biogenic habitat and a 100% association rate for juveniles.
2. Else et al. (2002) found a significant correlation of 0.37 between abundances of shortspine thornyhead (*Sebastolobus alascanus*) and sponges in the Gulf of Alaska.
3. Buhl-Mortensen and Mortensen (2004) found 17 species of *Pandalus* shrimp, isopods, amphipods, copepods, and decapods associated with *Paragorgia arborea* and *Primnoa resedaeformis* in Nova Scotia, including an obligate associated copepod. These coral species are both found in Alaska. The authors state that shrimp counts from video records showed that visual inspection without physically disturbing colonies will generally not reveal the crustaceans hidden in coral colonies, suggesting that these crustaceans are likely more often associated with these corals than has been previously recognized.
4. Dean (2000) quantified nearshore association between several Alaskan fish species and nearshore vegetation types, explaining differences in association by species and predation risk.
5. Gibson (1994) found that the impact of habitat quantity on recruitment plays a major role in determining overall population size of flatfish, suggesting a mechanism for a linkage

between habitat quantity and carrying capacity. Food and predation refuge were among the factors considered most important in this linkage. Habitat quality was defined in this study as “food, predators, temperature, salinity, oxygen, habitat structure, water depth and hydrodynamics”.

6. Loher and Armstrong (2000), indicated that late age 0 to 1 + red king crabs were located only in the most complex habitat in their study in Auke Bay, Alaska. The authors stated that “The availability of complex habitat, defined simply as substrate rich in available crevice space that is scaled to the body size of the crab instars, appeared to be the primary determinant of the value of nursery habitat, and it is likely to be the critical factor determining early post-settlement survivorship within the population. Such considerations are vital to management of red king crab fisheries where complex nursery habitat is likely to be relatively rare and where conflicts with trawl fisheries and other anthropogenic disturbances to bottom habitat are a potential concern.”
7. Stevens (2003) and Stevens & Swiney (2003) highlighted the importance to settling red king crab larvae of biogenic oases, particularly hydroids, that may be easily disturbed by hard-on-bottom fishing activities. The study states that “Red king crab glaucothoes demonstrate similar preferences for structurally complex biological substrata in the laboratory as they do in the wild. Settlement on sand occurs only as a last resort and results in higher mortality. These results indicate the importance to settling larvae of biogenic oases that may be easily disturbed by hard-on-bottom fishing activities, and underscore the importance of conserving such habitats.”
8. Though some areas in the Bering Sea have been protected from bottom trawling, most of Golden king crab EFH is located in areas open to trawling. According to the EFH DEIS, golden king crab habitat includes “high relief living habitats, such as coral, and vertical substrates such as boulders, vertical walls, ledges, and deep water pinnacles...” (Appendix D, p. D-73)
9. Hoyt et al. (2002) identified substrate and habitat types utilized by Golden king crabs in Southeast Alaska that are not considered in the EFH DEIS.
10. Kanno et al. (2001) and Saitoh (1998) distinguished different subpopulations of Pacific cod in Japan and found local differentiation and genetic variation at different sites, contrasting the claim in EFH DEIS p. 3-9 that Pacific cod are genetically indistinguishable throughout their range.
11. Nasby-Lucas et al. (2002) found that groundfish are more abundant in areas with high habitat variability, suggesting that habitat heterogeneity contributes to productivity.
12. characterized rockfish habitat in the Aleutian Islands using historical data.
13. Richards (1986) and Richards (1987) found that several species of rockfish in British Columbia are more abundant in complex, hard substrate.
14. The NOAA Ocean Explorer website (NOAA O.E. 2002) documents observations of forests of Paragorgia corals that were absolutely teeming with basket stars and brittle stars, crustaceans, small fishes, and bright purple polychaete worms at about 1,000 meters depth on Warwick Seamount in the Gulf of Alaska.
15. Several studies also described rockfish habitat types (Carr 1991; Stein et al. 1992; Yoklavich et al. 2000; Johnson 2003; Jagielo 2003; Reuter & Spencer 2003).

Evidence for habitat-fishery linkages- Outside Alaska

1. Gotceitas & Brown (1993) showed that juvenile Atlantic cod exhibit preference for more complex habitat (cobble) when exposed to a predator and fewer juveniles being captured by the predator in complex habitat.
2. Gotceitas et al. 1995 found that an association with kelp provides safety from predation to juvenile cod.
3. Borg et al. (1997) showed that juvenile Atlantic cod show a strong preference for structural biogenic habitat, particularly at smaller sizes.
4. Cote et al. (2001) found that all age-classes of Atlantic cod used areas with kelp significantly more than other areas during the day, when there is higher predation risk.
5. In a two year study off Newfoundland, Laurel et al. (2003a) documented that habitat fragmentation increases predation risk for juvenile cod and that predation rates on juvenile cod were negatively correlated with patch size of structural biogenic habitat during both years. Their study (Laurel et al. 2003b) indicated a significant increase in cod abundance at sites enhanced with simulated eelgrass and a corresponding decrease in cod numbers at sites where eelgrass had been removed.
6. Lindholm et al. (2001) stated that habitat change caused by fishing has significant negative effects on juvenile Atlantic cod survivorship, suggesting marine protected areas as a means to ameliorate these negative effects. The authors indicate that "[post-settlement] survivorship of Atlantic cod is greater in habitats of higher complexity (e.g., pebble-cobble substratum with emergent epifauna > pebble-cobble > sand), where cover provides shelter from predators. Fishing with mobile gear such as bottom trawls and dredges reduces the complexity of seafloor habitats."
7. Turner et al. (1999) reviewed three fisheries in New Zealand and Australia and found that fishing has been associated with the degradation or loss of habitat structure through the removal of large epibenthic organisms, with concomitant effects on fish species which occupy these habitats.
8. Diaz (2003) found that a quantitative association for juvenile fishes between and within benthic habitats was found and related primarily to bedform size and amount of benthic structure and that small changes in habitat structure can make the difference between unacceptable and essential habitat for juvenile fishes. This study emphasized that fish-habitat linkages are strongest at juvenile life stages.
9. Lenihan and Peterson (1998) showed that fishing disturbance to biogenic reef habitat alters alters fish abundance and distribution when there are confounding environmental factors.
10. Epifanio et al. (2003) found that abundance of blue crabs was 7 times higher in biogenic substrate than adjacent open habitat, explained by higher food availability.
11. Kaiser et al. (1999) found that biogenic habitat structure is an important component of demersal fish habitat, and observed higher densities of gadoid fish species associated with structural fauna such as soft corals, hydroids, bryozoans, and sponges in the southern North Sea and eastern English Channel. Flatfish were found to be associated with sessile benthic epifauna, and deepwater sessile epifauna was found to be vulnerable to fishing disturbance.
12. Bradstock & Gordon (1983) found that trawling through bryozoan and coral grounds has affected the fish populations to the extent that an area has been closed to trawling to conserve stocks.

13. Sainsbury (1987) found that removal of sessile epifauna leads to a decline in demersal fish species that are closely associated with them on the continental shelf of northwestern Australia.
14. Sainsbury (1988) found a decrease in the number and variety of epifauna, particularly sponges, collected over time as by-catch. This reduction was associated with shifts in the fishery from high- to low-value species. A probable explanation was a positive role for epifauna in affecting the survivorship of the commercially valuable fish species.
15. Cote et al. (1999) found that alteration of physical substrate reduced nesting density, egg production, and suitable breeding areas for a species of substrate-spawning fish, *Salaria fluviatilis*.
16. Habitat structure influences predation rates on fish, particularly juvenile life stages (e.g., Heck & Thoman 1981, Persson & Eklov 1995, Rooker et al. 1998)
17. Herrnkind and Butler (1994) identified sponges as "benthic juvenile shelter" for spiny lobster in Florida Bay and were found to be one of the most productive sites for survival of postlarvae.
18. Mortensen et al. (1995) identified megafauna associated with deep sea coral bioherms in Norway, including redfish, saithe, squat lobsters, sponges, and gorgonians (*Paragorgia arborea*, *Paramuricea placomus*, *Primnoa resedaeformis*).
19. Husebo et al. (2002) found that the largest catches of redfish (*Sebastes marinus*) were made with long-line fleets set in deep sea coral reef habitats. Ling and tusk were also most numerous in coral habitats, although not statistically significant. Fish caught in coral habitats tended to be larger in size than in non-coral habitats. Reasons for the associations were feeding and physical structure.
20. The argument that structural habitat contributes to carrying capacity is supported by Beck's (1995) study of stone crabs, which found that habitat structural complexity can facilitate species persistence by providing refuges and the availability of refuges may control the size of many populations. These findings support the hypothesis that shelter availability is a demographic bottleneck that affects the growth and fecundity of large stone crabs. The author asserted that habitat structural complexity may affect both the size of populations and the size of individuals within the population.
21. Cranfield et al. (2001) found that alterations to structural benthic habitats (oyster reefs) reduced the density of associated blue cod in New Zealand. This suggests that reducing the quality of benthic habitats will reduce the carrying capacity of fish through density-dependence. Kramer et al. (1997) furthered the density-dependence argument, finding that as a habitat becomes saturated, fish will move to previously suboptimal habitats.
22. Rocha et al. (2000) found that sponges are habitat 'oases' in a desert of rubble and flat rocky bottoms in Brazil. The study identified fish associations with shallow and deepwater sponges, including several obligate associations and four endemic species of fishes associated with deepwater sponges.
23. Failure to reach favorable habitat is a common source of annual decrease in settlement of Pacific hake, *Merluccius productus* in California (Bailey 1981) and North Sea herring *Clupea harengus* (Bartsch 1989).
24. Mumby et al. (2004) described the fish biomass enhancement function of mangrove habitats in Belize and Mexico as a result of the intermediate nursery habitat that alleviated a predatory bottleneck for juvenile fish. Even though mangroves were not essential to these

- species, they provided large, superadditive productivity benefits. The study also identified an obligate habitat association between rainbow parrotfish and mangrove habitat.
25. Savino and Stein (1982) found reduced predation success by largemouth bass on bluegill in habitats of increased complexity.
 26. Gregory and Anderson (1997) found that some juvenile life stages of Atlantic cod exhibit a preference for coarse substrates and high bathymetric relief as a predator avoidance behavior.
 27. Tupper and Boutilier (1995) documented that postsettlement survival, subsequent juvenile densities, and growth rates of Atlantic cod were higher in more structurally complex habitats due to increased shelter availability and decreased predator efficiency in structurally complex habitats. The authors suggested that the population structure of Atlantic cod may be less influenced by patterns of larval supply than by postsettlement processes such as habitat-specific growth and mortality.
 28. Christiansen and Lutter (2003) cite evidence that commercially caught demersal and pelagic fish species, mainly redfish, saithe, ling and tusk, have a higher abundance near deep sea coral reefs and patches.
 29. Costello et al. (2003) found that fish species and abundance was greater on the deep sea coral habitat than surrounding seabed; 69% of species and 79% of abundance was associated with the reefs.
 30. Koenig et al. (2003) state that important predatory fish species have been seen aggregating around the larger coral structures of *Oculina* sp. deep sea corals off Florida, and small fish have taken up residence inside the modules.
 31. Scott and Risk (2003) found abundant fish associated with *Primnoa* which are not common in areas where coral is absent. The authors state that deep sea corals off Canada are being rapidly depleted by bottom trawling, which in turn appears to have an impact on fish stocks.
 32. Sulak et al. (2003) listed economically important fish species observed in deep sea coral habitat, several of which were restricted to this habitat. The authors also found several poorly known fish species associated with deep sea corals.

Habitat Associations constitute habitat fishery linkages

Several studies of the production of fish by fish habitats have simply identified all fisheries directly or indirectly associated with mangrove habitat and attribute the entire productivity of the fishery to the associated habitat (Naylor and Drew 1998, Ruitebeck 1988, Christensen 1982, Hamilton & Snedaker 1984, Gren & Soderqvist 1994, Ronnback 1999, Sathirathai & Barbier 2001, Ruitenbeck 1988; Costanza et al. 1997; Swallow 1990). For example, Naylor and Drew (1998) assumed one-to-one habitat fishery linkages for surgeonfish, rudderfish, jacks, parrotfish, grouper, squirrelfish, snapper, rabbitfish, mullet, emperorfish, goatfish, and octopus, based on respondents identifying either direct reliance on mangroves for food, reproduction, or protection or indirect reliance on mangroves for nutrient supplies that flow into the near-shore zone. These studies establish the precedent that until higher levels of habitat-fishery linkages are known (i.e. EFH Level 4), the EFH EIS should assume a one-to-one relationship between fish productivity and associated habitats to determine whether habitat impacts of fishing are minimal, whereas stock size in relation to MSST has not been cited anywhere in the literature as an appropriate indicator for habitat damage. In Alaska, the following FMP species are known to associate with corals and/or sponges: rougheye rockfish, redbanded rockfish, shortraker rockfish, sharpchin rockfish, Pacific Ocean perch, dusky rockfish, yelloweye rockfish, northern rockfish, shortspine thornyhead, several species of flatfish, Atka

mackerel, golden king crab, shrimp, Pacific cod, Pacific halibut, sculpin, walleye pollock, greenling, Greenland turbot, sablefish, and various non-commercial marine species (EFH DEIS; Else et al. 2002; NMFS 2004). Based on the research cited above, the EFH DEIS should assume a one-to-one linkage between these FMP species and corals and sponges.

Methodologies for determining EFH:

1. Auster et al. (2001b) reviewed trawl survey data and found that species distributions based on trawl survey data can be used as proxies for the distribution of seafloor habitats when species-habitat associations are known.
2. Rubec et al. (1999) recommended and discussed use of Habitat Suitability Index models for determining EFH as well as the fishery production functions of specific habitat features.
3. Therrien et al. (2000) identified spawning grounds, rearing areas, feeding grounds, and migration areas for commercial species off eastern New Brunswick.
4. Kaiser et al. (1999) state that "Some studies have already revealed subtle relationships between fishes and sediment type; however, this approach does not quantify habitat complexity." Therefore, EFH designation should consider structure forming organisms that form habitat complexity and examine fish associations with these organisms.
5. Warner et al. (2000) suggest that areas important to larval retention and accumulation processes must be included in reserves and in the designation of essential fish habitat. This finding is relevant to other studies that have identified these areas in Alaska (i.e. Bailey et al. 2003).

Determining "Minimal and Temporary" Adverse Impacts to EFH: Evidence

MSST is an inappropriate measure for minimal and temporary impacts. This approach relies on the assumption that there is no link between habitat and fisheries. MSY and MSST will be lower with habitat impacts than without. This approach inherently assumes that the habitat features whose LEI values were calculated in Appendix B do not in any way influence carrying capacity or growth rates of commercial species. The following studies present scientific evidence that is relevant to the determination of minimal and temporary adverse impacts to EFH: alternative approaches to the determination whether fishing impacts on EFH as minimal and temporary:

1. Leys and Lauzon (1998) found large deep water Hexactinellid sponges to be 220 years old with average growth rates of 1.98 cm/year. These sponges are also found throughout Alaska, particularly in the Aleutian Islands and Gulf of Alaska. This contradicts the EFH DEIS, which assumes much recovery rates for sponges. This strongly suggests that sponges be included in the hard coral category and that this category should have recovery times greater than 100 years.
2. Malecha and Stone (2003) found that damaged or dislodged sea whips (*Halipterus willemoesi*) in Alaska are much more vulnerable to predation by the nudibranch *Tritonia festiva*, that appeared to illicit a strong scavenging/predatory response to sea whips in contact with the seafloor.
3. DeAlteris et al. (1999) developed a quantitative model for different sensitivity and recovery times of habitat based on comparisons to natural disturbance regimes. This study was aimed specifically at identifying adverse impacts to EFH that are more than minimal and temporary and was not considered in the EFH DEIS.

4. DeGroot (1984) identified specific taxa that were more susceptible to trawl damage and suggested long-term changes in community composition as a result of trawling.
5. Jones (1992) review of trawl impact literature revealed that recovery time for deep sea benthos with little natural disturbance is on the scale of decades.
6. Kaiser et al. (2003) state that structurally complex habitats (e.g. sea-grass meadows, biogenic reefs) and those that are relatively undisturbed by natural perturbations (e.g. deep-water mud substrata) are more adversely affected by fishing than unconsolidated sediment habitats that occur in shallow coastal waters and have the longest recovery trajectories in terms of the recolonization of the habitat by the associated fauna. The authors state that emergent seabed organisms provide shelter for juvenile fishes, reducing their vulnerability to predation and recommend total and partial exclusion of towed bottom fishing gears.
7. Koslow et al. (2000) discusses the higher longevity and vulnerability of deepwater ecosystems to trawling, particularly on seamounts, which are known to have benthic fauna (i.e. corals) with high levels of endemism.
8. Lindeboom (2000) discusses evidence for long-term changes in benthos caused by trawling and recommends reducing fishing effort, modifying gear design, and closed areas.
9. MacDonald et al. (1996) developed sensitivity indices for different benthic habitat types, and found that fragile, slow recruiting animals are most susceptible to fishing disturbance.
10. Thrush & Dayton (2002) reviewed literature on habitat impacts of trawling finding that long-lived species in deeper waters are more susceptible to impacts and that structure-forming organisms affects biodiversity and commercial fish productivity.
11. Watling and Norse (1998) review paper on the effects of trawling found that trawling has long-lasting adverse impacts in areas with structural epifauna and areas with low natural disturbance, which in turn have effects on young life stages of commercial fish species.
12. Knowlton and Highsmith (2000) state that *Halichondria panicea*, a sponge found in the Gulf of Alaska, is long-lived.
13. Probert et al. (1997) finding of recovery times greater than 100 years for deep sea corals was not considered in Appendix B.
14. Risk et al. (2002) showed ages of over 300 years for *Primnoa resedaeformis*, suggesting recovery rates well over the 100 year recovery rate used in the Appendix B.
15. Heikoop et al. (2002) found deep sea corals (*Primnoa*) in Alaska and elsewhere have lifespans of several centuries. The authors describe the potential of these corals to contain extended records of surface productivity, deep ocean temperature and chemistry of value to climatologists and fisheries managers.
16. Cordes et al. (2001) found ages of 25-30 years for the deep sea coral *Anthomastus ritteri* in California's Monterey Bay, noting that the results agree with the general notion that growth rates are reduced and longevity increased in deep-sea species.
17. Roark et al. (2003) sampled corals from Hawaii and the Gulf of Alaska and dated a living *Gerardia* sp. to be 2700 years old and a black coral to be 2200 yrs old, using radiocarbon dating techniques.
18. Andrews et al. (2003) found growth rates of 1.74 cm/yr for *Primnoa*, 1 cm/yr for *Corallium*, and ages of 30 to over 200 years for deep-sea coral species of Davidson Seamount.
19. Koenig et al. (2003) found no evidence of recolonization of *Oculina* deep sea corals into denuded areas and offered two explanations: continued trawling and the rubble areas do not provide suitable substrate for planular settlement of coral larvae.

Determining “Minimal and Temporary” Adverse Impacts to EFH: Alternative Approaches

1. Snelgrove et al. (1997) advise a precautionary approach of “assume the worst” with respect to the impacts of fishing on habitat given current uncertainties.
2. Auster (2001a) applied management definitions for overfishing to a habitat context, based on uncertainty and potential costs of errors. Based on area impacted, distribution of habitats, and habitat-fishery linkages, Auster (2001a) proposed thresholds for triggering management actions.
3. Jones et al. (1996) discusses need to identify pathways of cause and effect, and developing ecological effect matrices in determining habitat impacts. In this approach, ecological effect matrix should be developed for each FMP species, showing all possible pathways for damage to FMP species productivity. Matrices should include all potential pathways as a precursor to identifying relevant information. The paper discusses the importance of identifying ecological indicators of habitat damage (this would be coral/sponge bycatch).
4. Swallow (1990) developed a model for impacts to fish habitat caused by coastal development that can be applied to any cause of destruction to fish habitat. Although the paper uses coastal development as the example cause of habitat damage, the results are applicable to any damage to fish habitat. The key results are that the failure to recognize interactions between fish habitat leads to excessive (more than minimal) damage to the habitat both in terms of the rate of habitat damage and the cumulative quantity of damage. A one-to-one linkage between habitat and fishery production is assumed. The EFH DEIS did not consider this approach in the determination of minimal impacts. If this model were used, it would certainly result in more than minimal and temporary adverse impacts to fish habitat as well as fish productivity.
5. Minns and Moore (2003) developed an approach for making decisions about fish habitat protection when there is uncertainty in fish-habitat linkages using interval analysis. Despite the uncertainty involved, simple habitat classification schemes involving 3-4 levels of productive capacity can provide bases for robust decisions regarding minimal and temporary impacts and levels of protection.
6. Rogers et al. (1999) recommended using vulnerable species and high resolution fishing effort distribution data as indicators for assessing the impacts of towed fishing gears.
7. Mangel (2000) stated that fish stock size and catch are inappropriate indicators of habitat damage, due to the lag time in population response. Instead, the author claims that habitat impacts must be evaluated based on habitat losses.

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